NET PRODUCTIVITY AND ECOLOGICAL EFFICIENCY OF *ANDROPOGON SCOPARIUS* GROWING IN AN OHIO RELICT PRAIRIE[1]

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Net productivity and ecological efficiency were determined for a grass, *Andropogon scoparius*, growing in a relict prairie in south central Ohio. Biomass, as determined by the short term harvest method, indicated that *Andropogon scoparius* composed approximately 90% of the prairie flora. The caloric value of this grass was determined for each sample and ecological efficiency was calculated by dividing the number of calories contained in a unit area of vegetation by the number of calories of photosynthetically effective radiation available to that vegetation. Peak standing crop was 119 g/m^2 on a deep soil area (30–45 cm) and 62 g/m^2 on a shallow soil area (15 cm). Over the growing season the biomass was significantly greater on the deeper soil. Weight of the litter was also measured, and this too was significantly greater on the deep soil. Caloric content was very consistent over the entire growing season and caloric values per unit dry weight were not significantly different in *Andropogon scoparius* from the deep and shallow soil areas. Maximum ecological efficiency was 0.65% on the deep soil during the period July 20–August 7, 1972.

Small relict prairie areas are found in Adams County in south central Ohio. Existing primarily on hills of the Interior Low Plateau, these areas contain some of the species characteristic of the tall-grass prairie, *Andropogon gerardi*, *Andropogon scoparius*, and *Sorghastrum nutans*. The present study involves an analysis of the net productivity and ecological efficiency of the dominant grass species, *Andropogon scoparius*, growing in one of these relict prairies.

The study site is located south of the Wisconsin glacial limits, near Lynx, Ohio. The prairie occupies about 1 ha and is on the east-facing slope of a hill. Apparently the area was never cultivated and, according to a native of the region, it has not been grazed for at least 60 years. The soil is shallow and overlies a layer of limestone. The prairie can be divided into two regions on the basis of soil depth. Over most of the area the soil is 30–45 cm in depth but in the northeast section the depth is 15 cm or less. Because of this difference in soil depth the productivity and efficiency of the two areas were analyzed separately.

MATERIALS AND METHODS

Net productivity was determined by the short-term harvest method (Odum, 1960). All above-ground vegetation in a randomly-placed quadrat, 1 m^2, was cut and the grasses present sorted into 2 categories: Litter and green material. Standing dead material and ground litter were not separated; however, green material was sorted to species. Both litter and green material were dried at 90°C for 24 hours and weighed. Oven-dried weights (biomass) are presented as g/m^2. Triplicate samples were taken from each of the shallow and deep soil areas at 2 week intervals from April 22, 1972 to October 8, 1972. Vegetation samples from the deep and shallow soil plots were kept separate for all measurements and calculations. Because of the difficulty in obtaining intact roots and in extricating gravel from the roots, an analysis of root production was not undertaken. Herbivore consumption was assumed to be small, therefore no correction was made for these losses in productivity.

Ecological efficiency is the number of calories contained in a unit area of vegetation divided by the calories of photosynthetically-effective radiant energy available to that vegetation (Botkin and Malone, 1968). To determine the number of calories captured and stored in the vegetation as net productivity, the increase in biomass (production) during any sampling period was multiplied by the calories per gram of *A. scoparius* on the final date of that sampling

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period. Caloric determinations were made according to the procedure outlined in the Parr manual (1960). Caloric values were analyzed using Model I analysis of variance and the Student-Newman-Keuls test (Sokal and Rohlf, 1969).

Production data were expressed as cal/m² and were divided by the total calories of utilizable solar radiation per m² of ground surface in order to determine the ecological efficiency. Solar radiation was measured with a Weathermeasure Corporation R401 Solar Radiation Recorder (Pyranograph) from July 1, 1972 to October 8, 1972. Because this recorder measures total incident radiation, the total Langleys received for the sampling periods were multiplied by 0.47 in order to determine the number of calories in wavelengths effective in photosynthesis (Moir, 1969).

Separation of the grasses into species made it possible to determine the percent of total community vegetation represented by *A. scoparius*. This was done by summing the weight of *A. scoparius* and all other grasses from the 6 plots on a given sample date and dividing this total into the weight of *A. scoparius* alone. Data from all sample dates were then averaged. In order to make meaningful comparisons of our data to that collected from prairie sites where total community efficiencies were analyzed, it was necessary to divide the calculated efficiencies by the relative biomass of *A. scoparius*.

RESULTS AND DISCUSSION

Biomass data, expressed as g/m², are shown for each sample date in figure 1. On the deep soil biomass increased until August 1, after which it decreased rapidly. Production was not as great on the shallow soil area. The peak standing crop of *A. scoparius* was 119 g/m² on August 1 on the deep soil.

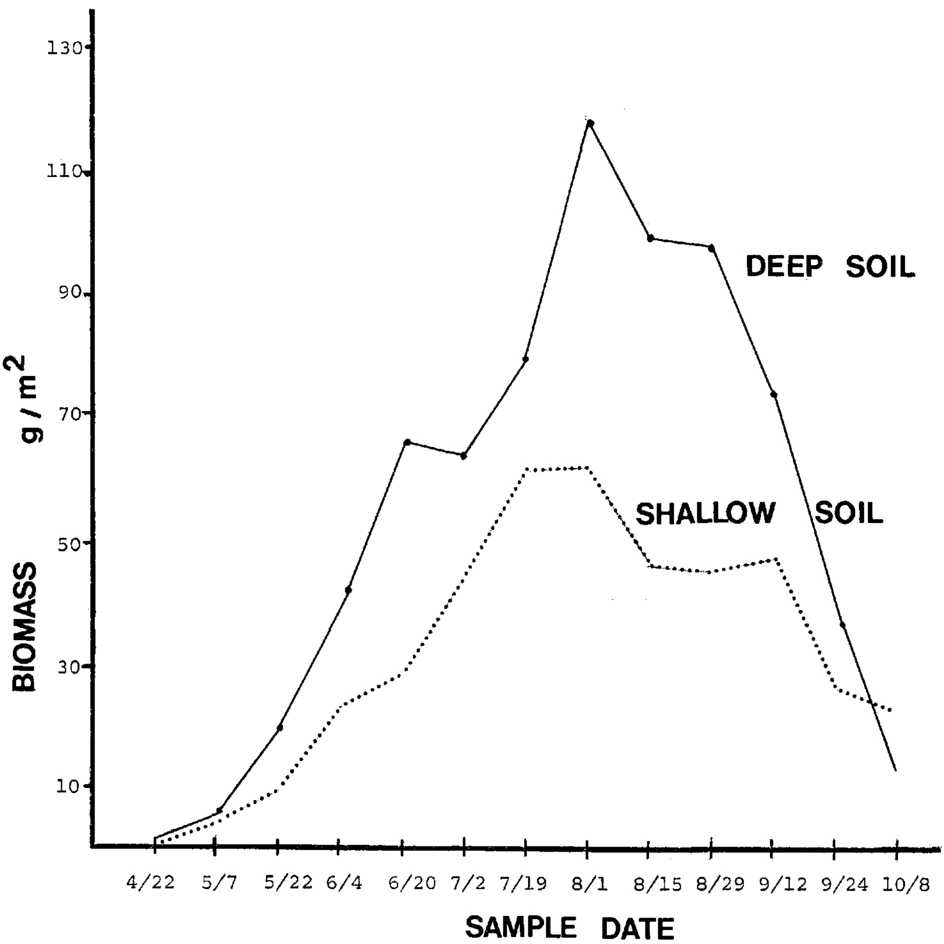

FIGURE 1. Change in biomass of green *A. scoparius* during the growing season expressed as g/m² (solid line-deep soil area, dashed line-shallow soil area).

This crop value is consistent with that of some other grassland communities studied by Golley (1965), who found that peak standing crop of *Andropogon virginicus* in an old field in Georgia declined from 253 g/m^2 to 95 g/m^2 during a 4-year period. Wali *et al* (1973) report a peak standing crop for *A. scoparius* in N. Dakota of 456 g/m^2, which was considerably greater than the peak standing crop found on the Lynx, Ohio prairie. The peak standing crop on the shallow soil on the Lynx, Ohio prairie (62 g/m^2) was only about half of the value on the deep soil.

Standing dead litter and ground litter were separated for the August 1 sample date. If it is assumed that all standing dead material was produced during the 1972 growing season, the weight of standing dead material (104 g/m^2) can be added to the biomass of the standing green *A. scoparius* (119 g/m^2) to give the maximum total production for that season. Dividing this figure by 365 days gives a net productivity of 0.61 $g/m^2/day$ for *A. scoparius* growing on the deep soil. According to Billings (1970) the annual net productivity of the original prairie was 0.5 to 2.0 g dry weight of shoots/m^2/day. The original prairie vegetation in the grassland biome grew on much deeper soils, presumed to be 2more or meters deep. Under these conditions roots of *A. scoparius* were able to extend to a depth of 2.4 m (Tomanek and Albertson, 1957). Wali *et al* (1973) found that the productivity of *A. scoparius* in N. Dakota was 6 $g/m^2/day$.

The biomass of *A. scoparius* on the deep soil was significantly greater than on the shallow soil. A t-test for paired comparisons showed that the difference between production on the deep and shallow soils was significant at the 0.02 level. McColley and Hodgkinson (1970) have found a positive correlation between production and soil depth in rangeland in Washington, and Hulett *et al* (1969) report a similar correlation with forage production on a mixed prairie in Kansas.

The change in weight of the litter over the study period is shown in Table 1. The amount of litter varied considerably among plots and from one sample date to another with no consistent pattern of change during the growing season. In spite of this variation, the weight of the litter on the deep soil was significantly greater than on the shallow soil. This was expected because biomass of the green material was greater on the deep soil.

TABLE 1

Weight and caloric content of litter from deep and shallow soil areas.

Sample Date	Weight (g/m^2)		Caloric content (cal/g)	
	Deep Soil	Shallow Soil	Deep Soil	Shallow Soil
April 22	116	66	4159	4082
May 7	85	94	4055	3906
May 22	104	67	4400	4414
June 4	94	32	4123	4384
June 20	91	66	4159	4286
July 2	102	69	4022	4313
July 19	80	55	4300	4379
August 1	104	65	4221	4300
August 15	73	52	4226	4243
August 29	140	50	3964	4146
September 12	87	56	3883	4226
September 24	61	45	4272	4235
October 8	130	115	4238	4121

Caloric Data. In most cases the caloric content of the vegetation on one sample date was not significantly different from the caloric content on another (Table 2). Where significant differences did occur, no consistent pattern of change was evident. The highest caloric contents were found on May 22 and August 15 in the grass from the deep soil area. However, there was considerable overlap of means when the data were analyzed

TABLE 2
Caloric content of green A. scoparius *expressed as cal/g.*

Sample Date	Deep soil area	Shallow soil area
April 22	4236	4290
May 7	——	4476
May 22	4465	4225
June 4	4243	4247
June 20	4160	4238
July 2	4330	4286
July 19	4327	4304
August 1	4323	4381
August 15	4363	4238
August 29	4298	4284
September 12	4158	4203
September 24	4246	4254
October 8	4246	4300

using the Student-Newman-Keuls test. The grand mean caloric value of *A. scoparius* growing on the deep soil was 4282 cal/g and on the shallow soil 4291 cal/g. The difference is not significant.

Generally, caloric content was higher in the litter from the shallow soil area than from the deep soil area (Table 1). The average caloric content over the growing season was 4233 on the shallow soil and 4155 on the deep soil. The difference was not significant.

Ecological efficiency was calculated for the two periods for which solar radiation data were available, July 3–July 19 and July 20–August 7, the latter period corresponded with the time of peak production. The ecological efficiency for the first period was 0.16% for the deep soil and 0.18% for the shallow soil. For the second period efficiencies were 0.65% and 0.008% for the deep and shallow soils respectively. The highest ecological efficiency for *A. scoparius* found at Lynx, Ohio was 0.65%. Kucera *et al* (1967) reported an efficiency of 1.21% in a tallgrass prairie in Missouri based on the growth of both roots and shoots of the dominant grass, *Andropogon gerardi*. Since root production accounted for about 50% of the total production, efficiencies based on above-ground vegetation could only be expected to be about half of this or approximately 0.60%. The efficiency of grass on the Missouri prairie, however, must still be considered to be higher than on the Lynx, Ohio prairie because the measurement at Lynx took place over the period of peak production, while the data from Missouri represent the average over two entire growing seasons (April-September). It can be seen from the first sample period at Lynx, Ohio (July 7–19) that efficiency was lower earlier in the season. Thus, an efficiency value determined for the entire growing season would be considerably lower than the maximum of 0.65% observed. The prairie at Lynx, Ohio supports many of the same species as the tall-grass prairie yet this prairie site is located on shallow, limy soils within the deciduous forest. The adversity of these conditions is apparently reflected in the lower productivity and ecological efficiency of the dominant species of these relict communities.

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